Perhaps the most satisfactory bronze metal is the alloy used in France for more than a century. It contains 91.60 per cent of copper, 5.33 per cent of zinc, 1.70 per cent of tin, and 1.37 per cent of lead. Somewhat more zinc is taken for articles to be gilded.

Bismuth Bronze.—Copper, 52 parts; nickel, 30 parts; zinc, 12 parts; lead, 5 parts; bismuth, 1 part. For metallic mirrors, lamp reflectors, etc.

Gun Bronze.—See Phosphor Bronze under this title.

Japanese Bronzes.—The formulas given below contain a large percentage of lead, which greatly improves the patina. The ingredients and the ratio of their parts for several sorts of modern Japanese bronze follow:

I.—Copper, 81.62 per cent; tin, 4.61 per cent; lead, 10.21 per cent.

II.—Copper, 76.60 per cent; tin, 4.38 per cent; lead, 11.88 per cent; zinc, 6.53 per cent.

III.—Copper, 88.55 per cent; tin, 2.42 per cent; lead, 4.72 per cent; zinc, 3.20 per cent.

Sometimes a little antimony is added just before casting, and such a composition would be represented more nearly by this formula:

IV.—Copper, 68.25 per cent; tin, 5.47 per cent; zinc, 8.88 per cent; lead, 17.06 per cent; antimony, 0.34 per cent.

For imitation Japanese bronze, see Plating under Bronzing.

Machine Bronze.—I.—Copper, 89 per cent; tin, 11 per cent.

II.—Copper, 80 per cent; tin, 16 per cent.

Phosphor Bronze.—Phosphor bronze is bronze containing varying amounts of phosphorus, from a few hundredths of 1 per cent to 1 or 2 per cent. Bronze containing simply copper and tin is very liable to be defective from the presence of oxygen, sulphur, or occluded gases. Oxygen causes the metal to be spongy and weak. Sulphur and occluded gases cause porosity. Oxygen gets into the metal by absorption from the air. It can be eliminated by adding to the metal something which combines with the oxygen and then fluxes off. Such deoxidizers are zinc, antimony, aluminum, manganese, silicon, and phosphorus. Sulphur and occluded gases can be eliminated by melting the metal, exposing it to the air, and letting it thus absorb some oxygen, which then burns the sulphur and gas. The oxygen can then be removed by adding one of the above-mentioned deoxidizers. The important use of phosphorus in bronze is, therefore, to remove oxygen and also indirectly to destroy occluded gas and sulphur.

A bronze is sometimes made with an extra high percentage of phosphorus, namely, 6 per cent. This alloy is made so as to have phosphorus in convenient form for use, and the process of manufacture is as follows: Ninety pounds of copper are melted under charcoal in a No. 70 crucible, which holds about 200 pounds of metal when full; 11 pounds of tin are added and the metal is allowed to become hot. The crucible is then removed from the furnace and 7 pounds of phosphorus are introduced in the following manner: A 3-gallon stone jar, half full of dilute solution of blue vitriol, is weighed. Then the weights are increased 7 pounds, and phosphorus in sticks about 4 inches long is added till the scales balance again. The phosphorus is left in this solution half an hour or longer, the phosphorus being given a coating of copper, so that it may be dried and exposed to the air without igniting. Have ready a pan about 30 inches square and 6 inches deep, containing about 2 inches of water. Over the water is a wire netting, which is laid loose on ledges or supports along the inner sides of the pan. On the netting is blotting paper, and on this the phosphorus is laid to dry when taken out of the blue-vitriol solution. The pan also has a lid which can be put down in case of ignition of the phosphorus.

The phosphorus is now ready for introduction into the metal. This is done by means of a cup-shaped instrument called a retort or phosphorizer. One man holds the retort on the rim of the crucible in a horizontal position. A second man takes about three pieces of phosphorus and throws them into the retort. The first man then immediately plunges the mouth of the retort below the surface of the metal before the phosphorus has a chance to fall or flow out. Of course the phosphorus immediately melts and also begins to volatilize. As the phosphorus comes in contact with the metal, it combines with it. This process is continued till all the 7 pounds of phosphorus has been put into the metal. The metal is then poured into slabs about 3 inches by 4 inches by 1 inch thick. The metal is so hard that a greater thickness would make it difficult to break it up. When finished, the metal contains, by analysis, 6 per cent of phosphorus. When phosphorus is to be added to metal, a little of this hardener is employed.

Copper is a soft, ductile metal, with its melting point at about 2,000° F. Mol-

ten copper has the marked property of absorbing various gases. It is for this reason that it is so difficult to make sound castings of clear copper. Molten copper combines readily with the oxygen of the air, forming oxide of copper, which dissolves in the copper and mixes homogeneously with it.

A casting made from such metal would be very spongy. The bad effect of oxygen is intended to be overcome by adding zinc to the extent of 1 per cent or more. This result can be much more effectively attained by the use of aluminum, manganese, or phosphorus. The action of these substances is to combine with the oxygen, and as the product formed separates and goes to the surface, the metal is left in a sound condition. Aluminum and manganese deoxidize copper and bronze very effectively, and the oxide formed goes to the surface as a scum. When a casting is made from such metal, the oxide or scum, instead of freeing itself from the casting perfectly, generally remains in the top part of the casting mixed with the metal, as a fractured surface will show. Phosphorus deoxidizes copper, and the oxide formed leaves the metal in the form of a gas, so that a casting made from such metal shows a clean fracture throughout, although the metal is not so dense as when aluminum or manganese is used.

Copper also has the property of absorbing or occluding carbon monoxide. But the carbonic oxide thus absorbed is in a different condition from the oxygen absorbed. When oxygen is absorbed by copper, the oxygen combines chemically with the copper and loses its own identity as a gas. But when coal gas is absorbed by the copper, it keeps its own physical identity and simply exists in the copper in a state of solution. All natural waters, such as lake water, river water, spring water, etc., contain air in solution or occlusion. When such water is cooled and frozen, just at the time of changing from the liquid to the solid state, the dissolved gas separates and forms air bubbles, which remain entangled in the ice. The carbonic oxide which is dissolved or occluded in copper acts in exactly the same way.

Hydrogen acts in exactly the same manner as carbonic oxide. Sulphur also has a bad effect upon copper and bronze. Sulphur combines with copper and other metals, forming sulphide of copper, etc. When molten copper or bronze containing sulphur comes in contact with air it absorbs some oxygen, and this in turn combines with the sulphur present, forming sulphur dioxide, which is a gas which remains occluded in the metal.

Tin is a soft, white metal, melting at 440° F. Toward gases it acts something like copper, but not in so marked a degree. Although copper and tin are both soft, yet when mixed they make a harder metal. When bronze cools from the molten state, the copper and the copper-tin alloy tend to crystallize by themselves. The quicker the cooling occurs the less separation will there be, and also the fracture will be more homogeneous in appearance.

Gun bronze contains copper and tin in the proportion of 9 or 10 parts of copper to 1 of tin. This is the metal used when an ordinary bronze casting is wanted. A harder bronze is copper and tin in the ratio of 6 to 1. This is often used as a bearing metal. When either of these metals is to be turned in the machine shop, they should contain about 3 per cent of lead, which will make them work very much better, but it also decreases their tensile strength. Bearing metal now generally contains about 10 per cent of lead, with copper and tin in varying ratios. The large percentage of lead is put in that the metal may wear away slower. Lead, although a metal having properties similar to tin, acts entirely different toward copper. Copper and tin have a good deal of affinity for each other, but copper and lead show no attraction at all for each other. Copper and tin mix in all proportions, but copper and lead mix only to a very limited extent. About 3 per cent of lead can be mixed with copper. With bronze about 15 per cent to 20 per cent of lead can be mixed. In bearing bronze the lead keeps its own physical properties, so that the constituent lead melts long before the metal attains a red heat. It sometimes happens when a bearing runs warm that the lead actually sweats out and forms pimples on the metal. Or, sometimes, in remelting a bearing bronze casting the lead may be seen to drop out while the metal is warming up. All of these metals, however, should contain something to flux or deoxidize them, such as zinc, manganese, aluminum, silicon, antimony, or phosphorus.

The phosphor bronze bearing metal in vogue has the following composition: Copper, 79.7 per cent; tin, 10 per cent; lead, 10 per cent; and phosphorus, 0.3 per cent.

Melt 140 pounds of copper in a No. 70 pot, covering with charcoal. When copper is all melted, add 17½ pounds of tin to 17½ pounds of lead, and allow the metal to become sufficiently warm, but

not any hotter than is needed. Then add 10 pounds of "hardener" (made as previously described) and stir well. Remove from furnace, skim off the charcoal, cool the metal with gates to as low a temperature as is consistent with getting a good casting, stir well again, and pour. The molds for this kind of work are faced with plumbago.

There are several firms that make phosphor-bronze bearings with a composition similar to the above one, and most of them, or perhaps all, make it by melting the metals and then charging with phosphorus to the extent of 0.7 to 1 per cent. But some metal from all brands contains occluded gas. So that after such metal is cast (in about two minutes or so) the metal will ooze or sweat out through the gate, and such a casting will be found to be porous. But not one such experience with metal made as described above has yet been found.

This practical point should be heeded, viz., that pig phosphor bronze should be brought to the specifications that the metal should have shrunk in the ingot mold in cooling, as shown by the concave surface of the upper side, and that it should make a casting in a sand mold without rising in the gate after being poured.

In bearing metal, occluded gas is very objectionable, because the gas, in trying to free itself, shoves the very hard copper-tin compound (which has a low melting point and remains liquid after the copper has begun to set) into spots, and thus causes hard spots in the metal.

Phosphorus is very dangerous to handle, and there is great risk from fire with it, so that many would not care to handle the phosphorus itself. But phosphor copper containing 5 per cent of phosphorus, and phosphor tin containing 2 to 7 per cent of phosphorus, and several other such alloys can be obtained in the market. It may be suggested to those who wish to make phosphor bronze, but do not want to handle phosphorus itself, to make it by using the proper amounts of one of these high phosphorus alloys. In using phosphorus it is only necessary to use enough to thoroughly deoxidize the metal, say 0.3 per cent. More than this will make the metal harder, but not any sounder.

Phosphor bronze is not a special kind of alloy, but any bronze can be made into phosphor bronze; it is, in fact, simply a deoxidized bronze, produced under treatment with phosphorus compounds.

Although the effect of phosphorus in improving the quality of bronze has been known for more than fifty years, it is only of late that the mode for preparing phosphor bronze has been perfected. It is now manufactured in many localities. Besides its action in reducing the oxides dissolved in the alloy, the phosphorus exerts another very material influence upon the properties of the bronze. The ordinary bronzes consist of mixtures in which the copper is really the only crystallized constituent, since the tin crystallizes with great difficulty. As a consequence of this dissimilarity in the nature of the two metals, the alloy is not so solid as it would be if both were crystallized. The phosphorus causes the tin to crystallize, and the result is a more homogeneous mixture of the two metals.

If enough phosphorus is added, so that its presence can be detected in the finished bronze, the latter may be considered an alloy of crystallized phosphor tin with copper. If the content of phosphor is still more increased, a part of the copper combines with the phosphorus, and the bronze then contains, besides copper and tin, compounds of crystallized copper phosphide with phosphide of tin. The strength and tenacity of the bronze are not lessened by a larger amount of phosphorus, and its hardness is considerably increased. Most phosphor bronzes are equal in this respect to the best steel, and some even surpass it in general properties.

The phosphorus is added to the bronze in the form of copper phosphide or phosphide of tin, the two being sometimes used together. They must be specially prepared for this purpose, and the best methods will be here given. Copper phosphide is prepared by heating a mixture of 4 parts of superphosphate of lime, 2 parts of granulated copper, and 1 part of finely pulverized coal in a crucible at a temperature not too high. The melted copper phosphide, containing 14 per cent of phosphorus, separates on the bottom of the crucible.

Tin phosphide is prepared as follows: Place a bar of zinc in an aqueous solution of tin chloride. The tin will be separated in the form of a sponge-like mass. Collect it, and put it into a crucible, upon the bottom of which sticks of phosphorus have been placed. Press the tin tightly into the crucible, and expose to a gentle heat. Continue the heating until flames of burning phosphorus are no longer observed on the crucible. The pure tin phosphide, in the form of a coarsely crystalline mass, tin-white in color, will be found on the bottom of the crucible.

To prepare the phosphor bronze, the

alloy to be treated is melted in the usual way, and small pieces of the copper phosphide and tin phosphide are added.

Phosphor bronze, properly prepared, has nearly the same melting point as that of ordinary bronze. In cooling, however, it has the peculiarity of passing directly from the liquid to the solid state, without first becoming thickly fluid. In a melted state it retains a perfectly bright surface, while ordinary bronze in this condition is always covered with a thin film of oxide.

If phosphor bronze is kept for a long time at the melting point, there is not any loss of tin, but the amount of phosphorus is slightly diminished.

The most valuable properties of phosphor bronze are its extraordinary tenacity and strength. It can be rolled, hammered, and stretched cold, and its strength is nearly double that of the best ordinary bronze. It is principally used in cases where great strength and power of resistance to outward influences are required, as, for instance, in objects which are to be exposed to the action of sea water.

Phosphor bronze containing about 4 per cent of tin is excellently well adapted for sheet bronze. With not more than 5 per cent of tin, it can be used, forged, for firearms. Seven to 10 per cent of tin gives the greatest hardness, and such bronze is especially suited to the manufacture of axle bearings, cylinders for steam fire engines, cogwheels, and, in general, for parts of machines where great strength and hardness are required. Phosphor bronze, if exposed to the air, soon becomes covered with a beautiful, closely adhering patina, and is therefore well adapted to purposes of art. The amount of phosphorus added varies from 0.25 to 2.5 per cent, according to the purpose of the bronze. The composition of a number of kinds of phosphor bronze is given below:

	Copper	Tin	Zinc	Lead	Iron	Phosphorus
I.	85.55	9.85	3.77	0.62	trs.	0.05
II.	.....	4–15	.....	4–15	....	0.5–3
III.	....	4–15	8–20	4–15	....	.25–2
IV.	77.85	11.00	7.65	....	....	....
V.	72.50	8.00	17.00	....	....	....
VI.	73.50	6.00	19.00	....	....	....
VII.	74.50	11.00	11.00	....	....	....
VIII.	83.50	8.00	3.00	....	....	....
IX.	90.34	8.90	....	....	....	0.76
X.	90.86	8.56	....	....	....	0.196
XI.	94.71	4.39	....	....	....	0.053

I for axle bearings, II and III for harder and softer axle bearings, IV to VIII for railroad purposes, IV especially for valves of locomotives, V and VI axle bearings for wagons, VII for connecting rods, VIII for piston rods in hydraulic presses.

Steel Bronze.—Copper, 60; ferromanganese (containing 70 to 80 per cent manganese), 40; zinc, 15.

Silicon Bronze.—Silicon, similarly to phosphorus, acts as a deoxidizing agent, and the bronzes produced under its influence are very ductile and elastic, do not rust, and are very strong. On account of these qualities silicon bronze is much used for telegraph and telephone wires. The process of manufacture is similar to that of phosphor bronze; the silicon is used in the form of copper silicide. Some good silicon bronzes are as follows:

	I	II
Copper.........	97.12	97.37
Tin............	1.14	1.32
Zinc...........	1.10	1.27
Silicon.........	0.05	0.07

Sun Bronze.—The alloy called sun bronze contains 10 parts of aluminum, 30 to 50 parts of copper, and 40 to 60 parts of cobalt. The mixture known by the name of metalline has 25 per cent of aluminum, 30 of copper, 10 of iron, and 35 of cobalt. These alloys melt at a point approaching the melting point of copper, are tenacious, ductile, and very hard.

Tobin Bronze.—This alloy is nearly similar in composition and properties to Delta metal.

	I	II	III	IV
Copper...	61.203	59.00	61.20	82.67
Zinc.....	27.440	38.40	37.14	3.23
Tin......	0.906	2.16	0.90	12.40
Iron.....	0.180	0.11	0.18	0.10
Lead.....	0.359	0.31	0.35	2.14
Silver....	....	....	....	0.07
Phosphorus	....	....	....	0.005

The alloy marked IV is sometimes called deoxidized bronze.

Violet-colored bronze is 50 parts copper and 50 parts antimony.

CADMIUM ALLOYS:

See also Fusible Alloys.

Lipowitz's Alloy.—I.—This alloy is composed of cadmium, 3 parts; tin, 4; bismuth, 15; and lead, 8. The simplest method of preparation is to heat the metals, in small pieces, in a crucible, stirring constantly, as soon as fusion

begins, with a stick of hard wood. The stirring is important, in order to prevent the metals, whose specific gravity varies considerably, from being deposited in layers. The alloy softens at 140° F. and melts completely at 158° F. The color is silvery white, with a luster like polished silver, and the metal can be bent, hammered, and turned. These properties would make it valuable for many purposes where a beautiful appearance is of special importance, but on account of the considerable amount of cadmium and bismuth which it contains, it is rather expensive, and therefore limited in use. Casts of small animals, insects, lizards, etc., have been prepared from it, which were equal in sharpness to the best galvanoplastic work. Plaster of Paris is poured over the animal to be cast, and after sharp drying, the animal is removed and the mold filled up with Lipowitz's metal. The mold is placed in a vessel of water, and by heating to the boiling point the metal is melted and deposited in the finest impressions of the mold.

This alloy is most excellent for soldering tin, lead, Britannia metal, and nickel, being especially adapted to the last two metals on account of its silver-white color. But here again its costliness prevents its general use, and cheaper alloys possessing the same properties have been sought. In cases where the silver-white color and the low melting point are not of the first importance, the alloys given below may very well be used in the place of it.

II.—Cadmium alloy (melting point, 170° F.): Cadmium, 2 parts; tin, 3; lead, 11; bismuth, 16.

III.—Cadmium alloy (melting point, 167° F.): Cadmium, 10 parts; tin, 3; lead, 8; bismuth, 8.

Cadmium alloys (melting point, 203° F.):

	IV	V	VI	
Cadmium..........	1	1	1	parts
Tin................	2	3	1	"
Bismuth...........	3	5	2	"

VII.—A very fusible alloy, melting at 150° F., is composed of tin, 1 or 2 parts; lead, 2 or 3; bismuth, 4 or 15; cadmium, 1 or 2.

VIII.—Wood's alloy melts between 140° and 161.5° F. It is composed of lead, 4 parts; tin, 2; bismuth, 5 to 8; cadmium, 1 to 2. In color it resembles platinum, and is malleable to a certain extent.

IX.—Cadmium alloy (melting point, 179.5° F.): Cadmium, 1 part; lead, 6 parts; bismuth, 7. This, like the preceding, can be used for soldering in hot water.

X.—Cadmium alloy (melting point, 300° F.): Cadmium, 2 parts; tin, 4; lead, 2. This is an excellent soft solder, with a melting point about 86 degrees below that of lead and tin alone.

Cadmium Alloys with Gold, Silver, and Copper.—I.—Gold, 750 parts; silver, 166 parts; cadmium, 84 parts. A malleable and ductile alloy of green color.

II.—Gold, 750 parts; silver, 125 parts; and cadmium, 125 parts. Malleable and ductile alloy of yellowish-green hue.

III. — Gold, 746 parts; silver, 114 parts; copper, 97 parts; and cadmium, 43 parts. Likewise a malleable and ductile alloy of a peculiar green shade. All these alloys are suitable for plating. As regards their production, each must be carefully melted together from its ingredients in a covered crucible lined with coal dust, or in a graphite crucible. Next, the alloy has to be remelted in a graphite crucible with charcoal (or rosin powder) and borax. If, in spite thereof, a considerable portion of the cadmium should have evaporated, the alloy must be re-fused once more with an addition of cadmium.

ALLOYS FOR CASTING COINS, MEDALLIONS, ETC.

Alloys which fulfill the requirements of the medalist, and capable, therefore, of reproducing all details, are the following:

	I	II	
Tin................	3	6	parts
Lead...............	13	8	"
Bismuth............	6	14	"

III.—A soft alloy suitable to take impressions of woodcuts, coins, metals, engravings, etc., and which must melt at a low degree of heat, is made out of bismuth, 3 parts; tin, $1\frac{1}{2}$ parts; lead, $2\frac{1}{2}$ parts; and worn-out type, 1 part.

Acid-proof Alloy.—This alloy is characterized by its power of resisting the action of acids, and is therefore especially adapted to making cocks, pipes, etc., which are to come in contact with acid fluids. It is composed of copper, zinc, lead, tin, iron, nickel, cobalt, and antimony, in the following proportions:

Copper..............	74.75	parts
Zinc................	0.61	"
Lead................	16.35	"
Tin.................	0.91	"
Iron................	0.43	"
Nickel } Cobalt }	0.24	"
Antimony............	6.78	"

Albata Metal.—Copper, 40 parts; zinc, 32 parts; and nickel, 8 parts.

Alfenide Metal.—Copper, 60 parts; zinc, 30; nickel, 10; traces of iron.

Bath Metal.—This alloy is used especially in England for the manufacture of teapots, and is very popular owing to the fine white color it possesses. It takes a high polish, and articles made from this alloy acquire in the course of time, upon only being rubbed with a white cloth, a permanent silver luster. The composition of Bath metal is copper, 55 parts; zinc, 45 parts.

Baudoin Metal.—This is composed of 72 parts of copper, 16.6 of nickel, 1.8 of cobalt, 1 of zinc; ½ per cent of aluminum may be added.

CASTING COPPER:

Macht's Yellow Metal.—I.—This alloy consists of 33 parts of copper and 25 of zinc. It has a dark golden-yellow color, great tenacity, and can be forged at a red heat, properties which make it especially suitable for fine castings.

II.—Yellow.—Copper, 67 to 70 parts; zinc, 33 to 30 parts.

III.—Red.—Copper, 82 parts; zinc, 18 parts.

Copper Arsenic.—Arsenic imparts to copper a very fine white color, and makes it very hard and brittle. Before German silver was known, these alloys were sometimes used for the manufacture of such cast articles as were not to come in contact with iron. When exposed to the air, they soon lose their whiteness and take on a brownish shade. On account of this, as well as the poisonous character of the arsenic, they are very little used at the present time. Alloys of copper and arsenic are best prepared by pressing firmly into a crucible a mixture of 70 parts of copper and 30 of arsenic (the copper to be used in the form of fine shavings) and fusing this mixture in a furnace with a good draught, under a cover of glass.

Copper Iron.—The alloys of copper and iron are little used in the industries of the present day, but it would seem that in earlier times they were frequently prepared for the purpose of giving a considerable degree of hardness to copper; for in antique casts, consisting principally of copper, we regularly find large quantities of iron, which leads to the supposition that they were added intentionally.

These alloys, when of a certain composition, have considerable strength and hardness. With an increase in the quantity of the iron the hardness increases, but the solidity is lessened. A copper and iron alloy of considerable strength, and at the same time very hard, is made of copper, 66 parts; iron, 34. These alloys acquire, on exposure to air, an ugly color inclining toward black, and are therefore not adapted for articles of art.

Copper Nickel.—A. Morrell, of New York, has obtained a patent on a nickel-copper alloy which he claims is valuable on account of its noncorrosive qualities, therefore making it desirable for ships, boiler tubes, and other uses where the metal comes much in contact with water. The process of making the metal is by smelting ore containing sulphide of nickel and copper, and besemerizing the resultant matter. This is calcined in order to obtain the nickel and copper in the form of oxides. The latter are reduced in reverberating furnace with carbon, or the like, so as to produce an alloy which preferably contains 2 parts of nickel and 1 part of copper.

Delta Metal.—An alloy widely used for making parts of machinery, and also for artistic purposes, is the so-called Delta metal. This is a variety of brass hardened with iron; some manufacturers add small quantities of tin and lead; also, in some cases, nickel. The following analysis of Delta metal (from the factory at Düsseldorf) will show its usual composition:

	I	II	III	IV	V
Copper....	55.94	55.80	55.82	54.22	58.65
Zinc.......	41.61	40.07	41.41	42.25	38.95
Lead......	0.72	1.82	0.76	1.10	0.67
Iron.......	0.87	1.28	0.86	0.99	1.62
Manganese	0.81	0.96	1.38	1.09	....
Nickel.....	traces.	traces.	0.06	0.16	0.11
Phosphorus	0.013	0.011	traces.	0.02	....

I is cast, II hammered, III rolled, and IV hot-stamped metal. Delta metal is produced by heating zinc very strongly in crucibles (to about 1600° F.), and adding ferromanganese or "spiegeleisen," producing an alloy of 95 per cent zinc and 5 per cent of iron. Copper and brass and a very small amount of copper phosphate are also added.

Gong Metal.—A sonorous metal for cymbals, gongs, and tam-tams consists of 100 parts of copper with 25 parts tin. Ignite the piece after it is cast and plunge it into cold water immediately.

Production of Minargent.—This alloy consists of copper, 500 parts; nickel, 350; tungsten, 25, and aluminum, 5. The metal obtained possesses a handsome white color and greatly resembles silver.

Minofor.—The so-called Minofor metal is composed of copper, tin, antimony, zinc, and iron in the following proportions:

	I	II
Copper..........	3.26	4
Tin.............	67.53	66
Antimony........	17.00	20
Zinc............	8.94	9
Iron............	....	1

Minargent and Minofor are sometimes used in England for purposes in which the ordinary Britannia metal, 2 parts tin and 1 part antimony, might equally well be employed; the latter surpasses both of them in beauty of color, but they are, on the other hand, harder.

Retz Alloy.—This alloy, which resists the corrosive action of alkalies and acids, is composed of 15 parts of copper, 2.34 of tin, 1.82 of lead, and 1 of antimony. It can be utilized in the manufacture of receivers, for which porcelain and ebonite are usually employed.

Ruoltz Metal. — This comprises 20 parts of silver, 50 of copper, 30 of nickel. These proportions may, however, vary.

Tissier's Metal.—This alloy contains arsenic, is of a beautiful tombac red color, and very hard. Its composition varies a great deal, but the peculiar alloy which gives the name is composed of copper, 97 parts; zinc, 2 parts; arsenic, 1 or 2. It may be considered a brass with a very high percentage of copper, and hardened by the addition of arsenic. It is sometimes used for axle bearings, but other alloys are equally suitable for this purpose, and are to be preferred on account of the absence of arsenic, which is always dangerous.

FILE ALLOYS.—Many copper-tin alloys are employed for the making of files which, in distinction from the steel files, are designated composition files. Such alloys have the following compositions:

Geneva Composition Files.—

	I	II
Copper..........	64.4	62
Tin.............	18.0	20
Zinc............	10.0	10
Lead............	7.6	8

Vogel's Composition Files.—

	III	IV	V
Copper......	57.0	61.5	73.0
Tin.........	28.5	31.0	19.0
Zinc........	78.0	....	8.0
Lead........	7.0	8.5	8.0

VI.—Another alloy for composition files is copper, 8 parts; tin, 2; zinc, 1, and lead, 1—fused under a cover of borax.

EASILY FUSIBLE OR PLASTIC ALLOYS.

(These have a fusing point usually below 300° F.)

(See also Solders.)

I. **Rose's Alloy.** — Bismuth, 2 parts; lead, 1 part; tin, 1 part. Melting point, 200° F.

II. **Darcet Alloy.**—This is composed of 8 parts of bismuth, 5 of lead, and 3 of tin. It melts at 176° F. To impart greater fusibility, $\frac{1}{16}$ part of mercury is added; the fusing is then lowered to 149° F.

III.—Newton alloy melts at 212° F., and is composed of 5 parts of bismuth, 2 of lead, and 3 of tin.

IV.—**Wood's Metal.**—

Tin................	2 parts
Lead...............	4 parts
Bismuth..........	5 to 8 parts

This silvery, fine-grained alloy fuses between 151° and 162° F., and is excellently adapted to soldering.

V.—Bismuth, 7 parts; lead, 6 parts; cadmium, 1 part. Melting point, 180° F.

VI.—Bismuth, 7 to 8 parts; lead, 4; tin, 2; cadmium, 1 to 2. Melting point, 149° to 160° F.

Other easily fusible alloys:

	VII	VIII	IX
Lead............	1	2	3
Tin.............	1	2	3
Bismuth.........	1	1	1
Melting Point....	258° F.	283°	311°

Fusible Alloys for Electric Installations.—These alloys are employed in electric installations as current interrupters. Serving as conductors on a short length of circuit, they melt as soon as the current becomes too strong. Following is the composition of some of these alloys.

	Fusing temperature	Lead	Tin	Bismuth	Cadmium
I...	203° F.	250	500	500	...
II...	193° F.	397	...	532	71
III...	168° F.	344	94	500	62
IV...	153° F.	260	148	522	70
V...	150° F.	249	142	501	108
VI...	145° F.	267	136	500	100

These alloys are prepared by melting the lead in a stearine bath and adding successively, and during the cooling, first, the cadmium; second, the bismuth; third, the tin. It is absolutely necessary to proceed in this manner, since these metals fuse at temperatures ranging from 850° F. (for lead), to 551° F. (for tin).

Fusible Safety Alloys for Steam Boilers.—

	Bismuth	Lead	Zinc	Melting point	Atmos. pressure
I.....	8	5	3	212° F.	1
II.....	8	8	4	235° F.	1.5
III.....	8	8	3	253° F.	2
IV.....	8	10	8	266° F.	2.5
V.....	8	12	8	270° F.	3
VI.....	8	16	14	280° F.	3.5
VII.....	8	16	12	285° F.	4
VIII.....	8	22	24	309° F.	5
IX.....	8	32	36	320° F.	6
X.....	8	32	28	330° F.	7
XI.....	8	30	24	340° F.	8

Lipowitz Metal.—This amalgam is prepared as follows: Melt in a dish, cadmium, 3 parts, by weight; tin, 4 parts; bismuth, 15 parts; and lead, 8 parts, adding to the alloy, while still in fusion, 2 parts of quicksilver previously heated to about 212° F. The amalgamation proceeds easily and smoothly. The liquid mass in the dish, which should be taken from the fire immediately upon the introduction of the mercury, is stirred until the contents solidify. While Lipowitz alloy softens already at 140° F. and fuses perfectly at 158°, the amalgam has a still lower fusing point, which lies around $143\frac{3}{5}$° F.

This amalgam is excellently adapted for the production of impressions of various objects of nature, direct impressions of leaves, and other delicate parts of plants having been made with its aid which, in point of sharpness, are equal to the best plaster casts and have a very pleasing appearance. The amalgam has a silver-white color and a fine gloss. It is perfectly constant to atmospheric influences. This amalgam has also been used with good success for the making of small statuettes and busts, which are hollow and can be readily gilt or bronzed by electro-deposition. The production of small statues is successfully carried out by making a hollow gypsum mold of the articles to be cast and heating the mold evenly to about 140° F. A corresponding quantity of the molten amalgam is then poured in and the mold moved rapidly to and fro, so that the alloy is thrown against the sides all over. The shaking should be continued until it is certain that the amalgam has solidified. When the mold has cooled off it is taken apart and the seams removed by means of a sharp knife. If the operation is carried on correctly, a chasing of the cast mass becomes unnecessary, since the alloy fills out the finest depressions of the mold with the greatest sharpness.

Amalgam for Plaster.—Tin, 1 part; bismuth, 1 part; mercury, 1 part. Melt the bismuth and the tin together, and when the two metals are in fusion add the mercury while stirring. For use, rub up the amalgam with a little white of egg and brush like a varnish on the plaster articles.

Plastic Metal Composition.—I. Copper oxide is reduced by means of hydrogen or copper sulphate by boiling a solution of the same in water with some zinc filings in order to obtain entirely pure copper. Of the copper powder obtained in this manner, 20, 30, or 36 parts, by weight, according to the degree of hardness desired for the composition (the greater the quantity of copper used the harder will the composition become), are thoroughly moistened in a cast-iron or porcelain mortar with sulphuric acid of 1.85 specific gravity; 70 parts, by weight, of mercury are then added to this paste, the whole being constantly stirred. When all the copper has been thoroughly amalgamated with the mercury, the sulphuric acid is washed out again with boiling water, and in 12 hours after it has become cold the composition will be so hard that it can be polished. It is impervious to the action of dilute acids, alcohol, ether, and boiling water. It contains the same specific gravity, alike in the soft or the hard condition. When used as a cement, it can at any time be rendered soft and plastic in the following manner: If applied while hot and plastic to the deoxidized surfaces of two pieces of metal, these latter will unite so firmly that in about 10 or 12 hours the metal may be subjected to any mechanical process. The properties of this composition render it very useful for various purposes, and it forms a most effective cement for fine metal articles which cannot be soldered in fire.

II.—Bismuth, 5.5 parts; lead, 3; tin, 1.5.

III. Alloy d'Homburg. — Bismuth,

3 parts; lead, 3; tin, 3. This alloy is fusible at 251° F., and is of a silvery white. It is employed for reproductions of medals.

IV. Alloy Valentine Rose.—Bismuth, 4 to 6 parts; lead, 2 parts; tin, 2 to 3 parts. This alloy fuses at 212° to 250° F.

V. Alloy Rose père. — Bismuth, 2 parts; lead, 2; tin, 2. This alloy fuses at 199° F.

The remainder are plastic alloys for reproducing cuts, medals, coins, etc.:

VI.—Bismuth, 4 parts; lead, 2 parts; tin, 1 part.

VII.—Bismuth, 3 parts; lead, 3 parts; tin, 2 parts.

VIII.—Bismuth, 4 parts; lead, 2 parts; tin, 2 parts.

IX.—Bismuth, 5 parts; lead, 2 parts; tin, 3 parts.

X.—Bismuth, 2 parts; lead, 2 parts; tin, 2 parts.

Quick-Water. — That the amalgam may easily take hold of bronze objects and remain there, it is customary to cover the perfectly cleansed and shining article with a thin coat of mercury, which is usually accomplished by dipping it into a so-called quick-water bath.

In the form of minute globules the mercury immediately separates itself from the solution and clings to the bronze object, which thereupon presents the appearance of being plated with silver. After it has been well rinsed in clean water, the amalgam may be evenly and without difficulty applied with the scratch brush.

This quick-water (in reality a solution of mercurous nitrate), is made in the simplest manner by taking 10 parts of mercury and pouring over it 11 parts of nitric acid of a specific gravity equal to 1.33; now let it stand until every part of the mercury is dissolved; then, while stirring vigorously, add 540 parts of water. This solution must be kept in closed flasks or bottles to prevent impurities, such as dust, etc., from falling into it.

The preparatory work on the object to be gilded consists mainly in cleansing it from every trace of oxidation. First, it must be well annealed by placing it in a bed of glowing coal, care being exercised that the heating be uniform. When cooled, this piece is plunged into a highly diluted sulphuric-acid bath in order to dissolve in a measure the oxide. Next it is dipped in a 36° nitric-acid bath, of a specific gravity equal to 1.33, and brushed off with a long brush; it is now dipped into nitric acid into which a little lampblack and table salt have been thrown. It is now ready for washing in clean water and drying in unsoiled sawdust. It is of the greatest importance that the surface to be gilded should appear of a pale yellow tint all over. If it be too smooth the gold will not take hold easily, and if it be too dull it will require too much gold to cover it.

GOLD ALLOYS:

Colored Gold Alloys.—The alloys of gold with copper have a reddish tinge; those of gold with silver are whiter, and an alloy of gold, silver, and copper together is distinguished by a greenish tone. Manufacturers of gold ware make use of these different colors, one piece being frequently composed of several pieces of varying color. Below are given some of these alloys, with their colors:

	Gold	Silver	Copper	Steel	Cadmium
I..	2.6	1.0	....	....	....
II..	75.0	16.6	....	....	8.4
III..	74.6	11.4	9.7	....	4.3
IV..	75.0	12.6	....	....	12.5
V..	1.0	2.0	....	....	....
VI..	4.0	3.0	1.0	....	....
VII..	14.7	7.0	6.0	....	....
VIII..	14.7	9.0	4.0	....	....
IX..	3.0	1.0	1.0	....	....
X..	10.0	1.0	4.0	....	....
XI..	1.0	....	1.0	....	....
XII..	1.0	....	2.0	....	....
XIII..	30.0	3.0	....	2.0	....
XIV..	4.0	....	....	1.0	....
XV..	29.0	11.0	....	....	....
XVI..	1.3	....	....	1.0	....

Nos. I, II, III, and IV are green gold; No. V is pale yellow; Nos. VI, VII, and VIII bright yellow; Nos. IX and X pale red; Nos. XI and XII bright red; Nos. XIII, XIV, and XV gray; while No. XVI exhibits a bluish tint. The finished gold ware, before being put upon the market, is subjected to a special treatment, consisting either in the simple pickling or in the so-called coloring, which operation is conducted especially with alloys of low degree of fineness, the object being to give the layers a superficial layer of pure gold.

The presence of silver considerably modifies the color of gold, and the jeweler makes use of this property to obtain alloys of various shades. The following proportions are to be observed, viz.:

Color of Gold	Gold per 1,000	Silver per 1,000	Copper per 1,000
I. Green........	750	250	...
II. Dead leaves....	700	300	...
III. Sea green.......	600	400	...
IV. Pink..........	750	200	50
V. English yellow..	750	125	125
VI. English white...	750	150	100
VII. Whiter.........	750	170	80
VIII. Less white......	750	190	60
IX. Red...........	750	...	250

Other colored gold alloys are the following:

X. Blue.—Fine gold, 75; iron, 25.

XI. Dark Gray. — Fine gold, 94; iron, 6.

XII. Pale Gray. — Fine gold, 191; iron, 9.

XIII. Cassel Yellow. — Fine gold, 75; fine silver, 12½; rose copper, 12½.

The above figures are understood to be by weight.

The gold solders, known in France under the names of *soudures au quart* (13½ carat), *au tiers* (12 carat), and *au deux* (9 carat), are composed of 3, 2, or 1 part of gold respectively, with 1 part of an alloy consisting of two-thirds silver and one-third copper. Gold also forms with aluminum a series of alloys of greatly varying coloration, the most curious of them, composed of 22 parts of aluminum for 88 parts of gold, possessing a pretty purple shade. But all these alloys, of a highly crystalline base, are very brittle and cannot be worked, for which reason their handsome colorings have not yet been capable of being utilized.

Enameling Alloys.—I. **Transparent.**—This alloy should possess the property of transmitting rays of light so as to give the highest possible effect to the enamel. The alloy of gold for transparent green should be pale; a red or copper alloy does not do for green enamel, the copper has a tendency to darken the color and thus take away a part of its brilliancy. The following alloy for transparent green possesses about the nearest print, in color, to the enamel—which should represent, as near as possible, the color and brilliancy of the emerald—that can be arrived at:

	ozs.	dwts.	grs.
Fine gold.......	0	18	8
Fine silver.......	0	1	6
Fine copper......	0	0	10

No borax must be used in the melting of this alloy, it being of a more fusible nature than the ordinary alloy, and will not take so high a heat in enameling.

II. **Red Enamel.**—The enamel which forms this color being of a higher fusing point, if proper care be not taken, the gold will melt first, and the work become ruined. In the preparation of red enamel, the coloring matter is usually an oxide of gold, and this so raises the temperature at which it melts that, in order to prevent any mishap, the gold to be enameled on should be what is called a 22-carat red, that is, it should contain a preponderance of copper in the alloying mixture so as to raise the fusing point of the gold. The formula is:

	ozs.	dwts.	grs.
Fine gold.......	0	18	8
Fine silver.......	0	0	10
Fine copper......	0	1	6

Gold-leaf Alloys.—All gold made into leaf is more or less alloyed. The gold used by the goldbeater is alloyed according to the variety of color required. Fine gold is commonly supposed to be incapable of being reduced to thin leaves. This, however, is not the case, although its use for ordinary purposes is undesirable on account of its greater cost. It also adheres by contact of one leaf with another, thus causing spoiled material and wasted labor; but for work exposed to the weather it is much preferable, as it is more durable and does not tarnish or change color.

The following is a list of the principal classes of leaf recognized and ordinarily prepared by beaters with the proportion of alloy they contain:

	Gold grs.	Silver grs.	Copper grs.
I. Red gold...	456–460	...	20–24
II. Pale red...	464	...	16
III. Extra deep.	456	12	12
IV. Deep......	444	24	12
V. Citron.....	440	30	10
VI. Yellow....	408	72	....
VII. Pale yellow	384	96	....
VIII. Lemon....	360	120	
IX. Green or pale	312	168	....
X. White.....	240	240	....

Gold-Plate Alloys.— Gold, 92 parts; copper, 8 parts.

II.—Gold, 84 parts; copper, 16 parts.

III.—Gold, 75 parts; copper, 25 parts.

IMITATION GOLD.

I.—One hundred parts, by weight, of copper of the purest quality; 14 of zinc or tin; 6 of magnesia; ⅙ of sal ammoniac, limestone, and cream of tartar. The copper is first melted, then the magnesia, sal ammoniac, limestone, and cream of tartar in powder are added separately and gradually. The whole mass is kept stirred for a half hour, the zinc or tin being dropped in piece by piece, the stir-

ring being kept up till they melt. Finally the crucible is covered and the mass is kept in fusion 35 minutes and, the same being removed, the metal is poured into molds, and is then ready for use. The alloy thus made is said to be fine-grained, malleable, takes a high polish, and does not easily oxidize.

II.—An invention, patented in Germany, covers a metallic alloy, to take the place of gold, which, even if exposed for some time to the action of ammoniacal and acid vapors, does not oxidize or lose its gold color. It can be rolled and worked like gold and has the appearance of genuine gold without containing the slightest admixture of that metal. The alloy consists of copper and antimony in the approximate ratio of 100 to 6, and is produced by adding to molten copper, as soon as it has reached a certain degree of heat, the said percentage of antimony. When the antimony has likewise melted and entered into intimate union with the copper, some charcoal ashes, magnesium, and lime spar are added to the mass when the latter is still in the crucible.

III. **Aluminum Gold.** — This alloy, called Nuremberg gold, is used for making cheap gold ware, and is excellent for this purpose, as its color is exactly that of pure gold, and does not change in the air. Articles made of Nuremberg gold need no gilding, and retain their color under the hardest usage; even the fracture of this alloy shows the pure gold color. The composition is usually 90 parts of copper, 2.5 of gold, and 7.5 of aluminum.

IV.—Imitation gold, capable of being worked and drawn into wire, consists of 950 parts copper, 45 aluminum, and 2 to 5 of silver.

V.—Chrysochalk is similar in composition to Mannheim gold:

	I	II
Copper..........	90.5	58.68
Zinc............	7.9	40.22
Lead...........	1.6	1.90

In color it resembles gold, but quickly loses its beauty if exposed to the air, on account of the oxidation of the copper. It can, however, be kept bright for a long time by a coating of colorless varnish, which excludes the air and prevents oxidation. Chrysochalk is used for most of the ordinary imitations of gold. Cheap watch chains and jewelry are manufactured from it, and it is widely used by the manufacturers of imitation bronze ornaments.

Mannheim Gold or Similor.—Mannheim gold is composed of copper, zinc, and tin, in proportions about as follows:

	I	II
Copper.........	83.7	89.8
Zinc............	9.3	9.9
Tin............	7.0	0.6

It has a fine yellow color, and was formerly much used in making buttons and pressed articles resembling gold. Later alloys, however, surpass it in color, and it has fallen somewhat into disuse. One variety of Mannheim gold, so called, contains 1.40 parts of brass (composition 3 Cu_2 1 Zn) to 10 of copper and 0.1 of zinc.

Mosaic Gold.—This is an alloy composed—with slight deviations—of 100 parts of copper and 50 to 55 of zinc. It has a beautiful color, closely resembling that of gold, and is distinguished by a very fine grain, which makes it especially suitable for the manufacture of castings which are afterwards to be gilded. The best method of obtaining a thoroughly homogeneous mixture of the two metals is first to put into the crucible one-half of the zinc to be used, place the cover upon it, and fuse the mixture under a cover of borax at as low a temperature as possible. Have ready the other half of the zinc, cut into small pieces and heated almost to melting, and when the contents of the crucible are liquid throw it in, a small portion at a time, stirring constantly to effect as intimate a mixture of the metals as possible.

Oreïde or Oroïde (French Gold).—The so-called French gold, when polished, so closely resembles genuine gold in color that it can scarcely be distinguished from it. Besides its beautiful color, it has the valuable properties of being very ductile and tenacious, so that it can easily be stamped into any desired shape; it also takes a high polish. It is frequently used for the manufacture of spoons, forks, etc., but is unsuitable for this purpose on account of the large amount of copper contained in it, rendering it injurious to health. The directions for preparing this alloy vary greatly. The products of some Paris factories show the following composition:

	I	II	III
Copper..............	90	80.5	86.21
Zinc................	10	14.5	31.52
Tin................	..	...	0.48
Iron...............	..	...	0.24

A special receipt for oreïde is the following:

IV.—Melt 100 parts of copper and add, with constant stirring, 6 parts of magnesia, 3.6 of sal ammoniac, 1.8 of lime, and 9 of crude tartar. Stir again

thoroughly, and add 17 parts of granulated zinc, and after mixing it with the copper by vigorous stirring keep the alloy liquid for one hour. Then carefully remove the scum and pour off the alloy.

Pinchbeck.—This was first manufactured in England. Its dark gold color is the best imitation of gold alloyed with copper. Being very ductile, it can easily be rolled out into thin plates, which can be given any desired shape by stamping. It does not readily oxidize, and thus fulfills all the requirements for making cheap jewelry, which is its principal use.

Copper..........	88.8	93.6
Zinc.............	11.2	6.4

Or

Copper..........	2.1	1.28
Zinc.............	....	0.7
Brass............	1.0	0.7

Palladium Gold.—Alloys of gold, copper, silver, and palladium have a brownish-red color and are nearly as hard as iron. They are sometimes (although rarely) used for the bearings for the axles of the wheels of fine watches, as they invite little friction and do not rust in the air. The composition used in the Swiss and English watch factories consists usually of gold 18 parts, copper 13 parts, silver 11, and palladium 6.

Talmi Gold.—The name of talmi gold was first applied to articles of jewelry, chains, earrings, bracelets, etc., brought from Paris, and distinguished by beautiful workmanship, a low price, and great durability. Later, when this alloy had acquired a considerable reputation, articles were introduced under the same name, but which were really made of other metals, and which retained their beautiful gold color only as long as they were not used. The fine varieties of talmi gold are manufactured from brass, copper, or tombac, covered with a thin plate of gold, combined with the base by rolling, under strong pressure. The plates are then rolled out by passing through rollers, and the coating not only acquires considerable density, but adheres so closely to the base that the metal will keep its beautiful appearance for years. Of late, many articles of talmi gold have been introduced whose gold coating is produced by electroplating, and is in many cases so thin that hard rubbing will bring through the color of the base. Such articles, of course, are not durable. In genuine talmi gold, the coating, even though it may be thin, adheres very closely to the base, for the reason that the two metals are actually welded by the rolling, and also because alloyed gold is always used, which is much harder than pure gold. The pure gold of electroplating is very soft. The composition of some varieties of talmi gold are here given. It will be seen that the content of gold varies greatly, and the durability of the alloy will, of course, correspond to this. The alloys I, II, III are genuine Paris talmi gold; IV, V, and VI are electroplated imitations; and VII is an alloy of a wrong composition, to which the gold does not adhere firmly:

	Copper	Zinc	Tin	Iron	Gold
I.	89.9	9.3	....	....	1.3
II.	90.8	8.3	....	....	0.9
III.	90.0	8.9	....	....	0.9
IV.	90.7 88.2	89.0 11.4	....	....	0.5
V.	87.5 83.1	12.4 17.0	....	....	0.3
VI.	93.5 84.5	6.6 15.8	....	....	0.05
VII.	86.0	12.0	1.1	0.3	...

Japanese Alloys.—In Japan some specialties in metallic alloys are in use of which the composition is as follows:

Shadke consists of copper with from 1 to 10 per cent of gold. Articles made from this alloy are laid in a pickle of blue vitriol, alum, and verdigris, until they acquire a bluish-black color.

Gui-shi-bu-ichi is an alloy of copper containing 30 to 50 per cent of silver. It possesses a peculiar gray shade.

Mokume consists of several compositions. Thus, about 30 gold foils (genuine) are welded together with shadke, copper, silver, and gui-shi-bu-ichi and pierced. The pierced holes are, after firmly hammering together the plates, filled up with the above-named pickle.

The finest Japanese brass consists of 10 parts copper and 8 parts zinc, and is called siachu. The bell metal kara kane is composed of copper 10 parts, tin 10 parts, iron 0.5 part, and zinc 1.5 parts. The copper is first fused, then the remaining metals are added in rotation.

GERMAN SILVER OR ARGENTAN.

The composition of this alloy varies considerably, but from the adjoined figures an average may be found, which will represent, approximately, the normal composition:

Copper......	50 to 66 parts
Zinc.........	19 to 31 parts
Nickel.......	13 to 18 parts

The properties of the different kinds, such as their colo ductility, fusibility,

etc., vary with the proportions of the single metals. For making spoons, forks, cups, candlesticks, etc., the most suitable proportions are 50 parts of copper, 25 of zinc, and 25 of nickel. This metal has a beautiful blue-white color, and does not tarnish easily.

German silver is sometimes so brittle that a spoon, if allowed to fall upon the floor, will break; this, of course, indicates faulty composition. But the following table will show how the character of the alloy changes with the varying percentage of the metals composing it:

	Copper	Zinc	Nickel	Quality
I.	8	3.5	4	Finest quality.
II.	8	3.5	6	Beautiful, but refractory.
III.	8	6.5	3	Ordinary, readily fusible.
IV.	52	26.0	22	First quality.
V.	59	30.0	11	Second quality.
VI.	63	31.0	6	Third quality.

The following analyses give further particulars in regard to different kinds of German silver:

For sheet	Copper	Zinc	Nickel	Lead	Iron
(French)....	50.0	31.3	18.7	...	...
(French)....	50.0	30.0	20.0	...	...
(French)....	58.3	25.0	16.7	...	...
Vienna......	50.0	25.0	25.0	...	...
Vienna......	55.6	22.0	22.0	...	...
Vienna......	60.0	20.0	20.0	...	...
Berlin.......	54.0	28.0	18.0	...	...
Berlin.......	55.5	29.1	17.5	...	...
English.....	63.34	17.01	19.13	...	...
English.....	62.40	22.15	15.05	...	...
English.....	62.63	26.05	10.85	...	...
English.....	57.40	25.	13.0	...	3.0
Chinese.....	26.3	36.8	36.8	...	...
Chinese.....	43.8	40.6	15.6	...	...
Chinese.....	45.7	36.9	17.9	...	...
Chinese.....	40.4	25.4	31.6	...	2.6
Castings.....	48.5	24.3	24.3	2.9	...
Castings.....	54.5	21.8	21.8	1.9	...
Castings.....	58.3	19.4	19.4	2.9	...
Castings.....	57.8	27.1	14.3	0.8	...
Castings.....	57.	20.0	20.0	3.0	...

In some kinds of German silver are found varying quantities of iron, manganese, tin, and very frequently lead, added for the purpose of changing the properties of the alloy or cheapening the cost of production. But all these metals have a detrimental rather than a beneficial effect upon the general character of the alloy, and especially lessen its power of resistance to the action of dilute acids, one of its most valuable properties. Lead makes it more fusible; tin acts somewhat as in bronze, making it denser and more resonant, and enabling it to take a higher polish. With iron or manganese the alloy is whiter, but it becomes at the same time more refractory and its tendency toward brittleness is increased.

SUBSTITUTES FOR GERMAN SILVER.

There are many formulas for alloys which claim to be substitutes for German silver; but no one of them has yet become an article of general commerce. It will be sufficient to note these materials briefly, giving the composition of the most important.

Nickel Bronze.—This is prepared by fusing together very highly purified nickel (99.5 per cent) with copper, tin, and zinc. A bronze is produced containing 20 per cent of nickel, light-colored and very hard.

Bismuth Bronze.—

	I	II	III	IV
Copper.........	25.0	45.0	69.0	47.0
Nickel..........	24.0	32.5	10.0	30.9
Antimony.......	50.0	...	...	...
Bismuth........	1.0	1.0	1.0	0.1
Tin............	...	16.0	15.0	1.0
Zinc...........	...	21.5	20.0	21.0
Aluminum......	...	...	1.0	...

I is hard and very lustrous, suitable for lamp reflectors and axle bearings; II is hard, resonant, and not affected by sea water, for parts of ships, pipes, telegraph wires, and piano strings; III and IV are for cups, spoons, etc.

Manganese Argentan.—

Copper...........	52 to 50 parts
Nickel............	17 to 15 "
Zinc..............	5 to 10 "
Manganese	1 to 5 "
Copper, with 15 per cent phosphorus.	3 to 5 "

Readily cast for objects of art.

Aphtite.—

Iron..................	66 parts
Nickel...............	23 "
Tungsten.............	4 "
Copper...............	5 "

Arguzoid.—

Copper...........	55.78 parts
Zinc..............	23.198 "
Nickel	13.406 "
Tin...............	4.035 "
Lead..............	3.544 "

Silver white, almost ductile, suited for artistic purposes.

Ferro-Argentan.—

Copper	70.0 parts
Nickel	20.0 "
Zinc	5.5 "
Cadmium	4.5 "

Resembles silver; worked like German silver.

Silver Bronze.—Manganese, 18 per cent; aluminum, 1.2 per cent; silicium, 5 per cent; zinc, 13 per cent; copper, 67.5 per cent. The electric resistance of silver bronze is greater than that of German silver, hence it ought to be highly suitable for rheostats.

Instrument Alloys. — The following are suitable for physical and optical instruments, metallic mirrors, telescopes, etc.:

I.—Copper, 62 parts; tin, 33 parts; lead, 5 parts.

II.—Copper, 80; antimony, 11; lead, 9.

III.—Copper, 10; tin, 10; antimony, 10; lead, 40.

IV.—Copper, 30; tin, 50; silver, 2; arsenic, 1.

V.—Copper, 66; tin, 33.

VI.—Copper, 64; tin, 26.

VII.—Steel, 90; nickel, 10.

VIII.—Platinum, 60; copper, 40.

IX.—Platinum, 45; steel, 55.

X.—Platinum, 55; iron, 45.

XI.—Platinum, 15; steel, 85.

XII.—Platinum, 20; copper, 79; arsenic, 1.

XIII.—Platinum, 62; iron, 28; gold, 10.

XIV.—Gold, 48; zinc, 52.

XV.—Steel, 50; rhodium, 50.

XVI.—Platinum, 12; iridium, 88.

XVII.—Copper, 89.5; tin, 8.5; zinc, 2.

LEAD ALLOYS.

The following alloys, principally lead, are used for various purposes:

Bibra Alloy.—This contains 8 parts of bismuth, 9 of tin, and 38 to 40 of lead.

Metallic Coffins.—Tin, 40 parts; lead, 45 parts; copper, 15 parts.

Plates for Engraving.—I.—Lead, 84 parts; antimony, 16 parts.

II.—Lead, 86 parts; antimony, 14 parts.

III.—Lead, 87 parts; antimony, 12 parts; copper, 1 part.

IV.—Lead, 81 parts; antimony, 14 parts; tin, 5 parts.

V.—Lead, 73 parts; antimony, 17 parts; zinc, 10 parts.

VI.—Tin, 53 parts; lead, 43 parts; antimony, 4 parts.

Hard lead is made of lead, 84 parts; antimony, 16 parts.

Sheet Metal Alloy.—

Tin	35 parts
Lead	250 parts
Copper	2.5 parts
Zinc	0.5 part

This alloy has a fine white color, and can be readily rolled into thin sheets. For that reason it is well adapted for lining tea chests and for the production of tobacco and chocolate wrappers. The copper and zinc are used in the form of fine shavings. The alloy should be immediately cast into thin plates, which can then be passed through rolls.

MAGNETIC ALLOYS.

Alloys which can be magnetized most strongly are composed of copper, manganese, and aluminum, the quantities of manganese and aluminum being proportional to their atomic weights (55.0 to 27.1, or about 2 to 1). The maximum magnetization increases rapidly with increase of manganese, but alloys containing much manganese are exceedingly brittle and cannot be wrought. The highest practicable proportion of manganese at present is 24 per cent.

These magnetic alloys were studied by Hensler, Haupt, and Starck, and Gumlich has recently examined them at the Physikalisch - technische Reichsanstalt, with very remarkable and interesting results.

The two alloys examined were composed as follows:

Alloy I.—Copper, 61.5 per cent; manganese, 23.5 per cent, aluminum, 15 per cent; lead, 0.1 per cent, with traces of iron and silicon.

Alloy II.—Copper, 67.7 per cent; manganese, 20.5 per cent; aluminum, 10.7 per cent; lead, 1.2 per cent, with traces of iron and silicon.

Alloy II could be worked without difficulty, but alloy I was so brittle that it broke under the hammer. A bar 7 inches long and ¼ inch thick was obtained by grinding. This broke in two during the measurements, but, fortunately, without invalidating them. Such a material is evidently unsuited to practical uses.

The behavior of magnetic alloys at high temperatures is very peculiar. Alloy I is indifferent to temperature changes, which scarcely affect its magnetic properties, but the behavior of alloy II is very different. Prolonged heating to 230° F. produces a great increase in its capability of magnetization, which, after 544 hours' heating, rises from 1.9 to 3.2 kilo-

gauss, approaching the strength of alloy I. But when alloy II is heated to 329° F., its capability of magnetization fails again and the material suffers permanent injury, which can be partly, but not wholly, cured by prolonged heating.

Another singular phenomenon was exhibited by both of these alloys. When a bar of iron is magnetized by an electric current, it acquires its full magnetic strength almost instantaneously on the closure of the circuit. The magnetic alloys, on the contrary, do not attain their full magnetization for several minutes. In some of the experiments a gradual increase was observed even after the current had been flowing five minutes.

In magnetic strength alloy I proved far superior to alloy II, which contained smaller proportions of manganese and aluminum. Alloy I showed magnetic strengths up to 4.5 kilogauss, while the highest magnetization obtained with alloy II was only 1.9 kilogauss. But even alloy II may be called strongly magnetic, for its maximum magnetization is about one-tenth that of good wrought iron (18 to 20 kilogauss), or one-sixth that of cast iron (10 to 12 kilogauss). Alloy I is nearly equal in magnetic properties to nickel, which can be magnetized up to about 5 kilogauss.

MANGANESE ALLOYS:

Manganese bronze is a bronze deprived of its oxide by an admixture of manganese. The manganese is used as copper manganese containing 10 to 30 per cent manganese and added to the bronze to the amount of 0.5 to 2 per cent.

Manganese Copper.—The alloys of copper with manganese have a beautiful silvery color, considerable ductility, great hardness and tenacity, and are more readily fusible than ordinary bronze. A special characteristic is that they exactly fill out the molds, without the formation of blowholes, and present no difficulties in casting.

Cupromanganese is suitable for many purposes for which nothing else but bronze can advantageously be used, and the cost of its production is no greater than that of genuine bronze. In preparing the alloy, the copper is used in the form of fine grains, obtained by pouring melted copper into cold water. These copper grains are mixed with the dry oxide of manganese, and the mixture put into a crucible holding about 66 pounds. Enough space must be left in the crucible to allow a thick cover of charcoal, as the manganese oxidizes easily. The crucible is placed in a well-drawing wind furnace and subjected to a strong white heat. The oxide of manganese is completely reduced to manganese, which at once combines with the copper to form an alloy. In order to prevent, as far as possible, the access of air to the fusing mass, it is advisable to cover the crucible with a lid which has an aperture in the center for the escape of the carbonic oxide formed during the reduction.

When the reduction is complete and the metals fused, the lid is removed and the contents of the crucible stirred with an iron rod, in order to make the alloy as homogeneous as possible. By repeated remelting of the cupromanganese a considerable quantity of the manganese is reconverted into oxide; it is, therefore, advisable to make the casts directly from the crucible. When poured out, the alloy rapidly solidifies, and resembles in appearance good German silver. Another reason for avoiding remelting is that the crucible is strongly attacked by the cupromanganese, and can be used but a few times.

The best kinds of cupromanganese contain between 10 and 30 per cent of manganese. They have a beautiful white color, are hard, tougher than copper, and can be worked under the hammer or with rolls. Some varieties of cupromanganese which are especially valuable for technical purposes are given below:

	I	II	III	IV
Copper.....	75	60	65	60
Manganese.	25	25	20	20
Zinc........	..	15	5	..
Tin.........	..	..	..	10
Nickel......	..	..	10	10

Manganin.—This is an alloy of copper, nickel, and manganese for electric resistances.

MIRROR ALLOYS:

Amalgams for Mirrors.—I.—Tin, 70 parts; mercury, 30 parts.

II.—For curved mirrors. Tin, 1 part; lead, 1 part; bismuth, 1 part; mercury, 9 parts.

III.—For glass balls. Tin, 80 parts; mercury, 20 parts.

IV.—Metallic cement. Copper, 30 parts; mercury, 70 parts.

V.—Mirror metal.—Copper, 100 parts; tin, 50 parts; Chinese copper, 8 parts; lead, 1 part; antimony, 1 part.

Reflector Metals. — I. — (Cooper's.) Copper, 35 parts; platinum, 6; zinc, 2; tin, 16.5; arsenic, 1. On account of the hardness of this alloy, it takes a very high polish; it is impervious to the effects of the weather, and is therefore remark-

ably well adapted to the manufacture of mirrors for fine optical instruments.

II.—(Duppler's.) Zinc, 20 parts; silver, 80 parts.

III.—Copper, 66.22 parts; tin, 33.11 parts; arsenic, 0.67 part.

IV.—Copper, 64 parts; tin, 32 parts; arsenic, 4 parts.

V.—Copper, 82.18 parts; lead, 9.22 parts; antimony, 8.60 parts.

VI.—(Little's.) Copper, 69.01 parts; tin, 30.82 parts; zinc, 2.44 parts; arsenic, 1.83 parts.

Speculum Metal.—Alloys consisting of 2 parts of copper and 1 of tin can be very brilliantly polished, and will serve for mirrors. Good speculum metal should have a very fine-grained fracture, should be white and very hard, the highest degree of polish depending upon these qualities. A composition to meet these requirements must contain at least 35 to 36 per cent of copper. Attempts have frequently been made to increase the hardness of speculum metal by additions of nickel, antimony, and arsenic. With the exception of nickel, these substances have the effect of causing the metal to lose its high luster easily, any considerable quantity of arsenic in particular having this effect.

The real speculum metal seems to be a combination of the formula Cu_4Sn, composed of copper 68.21 per cent, tin 31.7. An alloy of this nature is sometimes separated from ordnance bronze by incorrect treatment, causing the so-called tin spots; but this has not the pure white color which distinguishes the speculum metal containing 31.5 per cent of tin. By increasing the percentage of copper the color gradually shades into yellow; with a larger amount of tin into blue. It is dangerous to increase the tin too much, as this changes the other properties of the alloy, and it becomes too brittle to be worked. Below is a table showing different compositions of speculum metal. The standard alloy is undoubtedly the best.

	Copper	Tin	Zinc	Arsenic	Silver
Standard alloy....	68.21	31.7	....	....	....
Otto's alloy....	68.5	31.5	...	....	....
Richardson's alloy	65.3	30.0	0.7	2.	2.
Sollit's alloy......	64.6	31.3	4.1	Nickel	....
Chinese speculum metal...	80.83	....	....	8.5	Antimony
Old Roman	63.39	19.05	....	17.29	Lead

PALLADIUM ALLOYS.

I.—An alloy of palladium 24 parts, gold 80, is white, hard as steel, unchangeable in the air, and can, like the other alloys of palladium, be used for dental purposes.

II.—Palladium 6 parts, gold 18, silver 11, and copper 13, gives a reddish-brown, hard, and very fine-grained alloy, suitable for the bearings of pivots in clock works.

The alloys of most of the other platinum metals, so called, are little used on account of their rarity and costliness. Iridium and rhodium give great hardness to steel, but the commercial rhodium and iridium steel, so called, frequently contains not a trace of either. The alloy of iridium with osmium has great hardness and resistance and is recommended for pivots, fine instruments, and points of ship compasses.

Palladium Silver.—This alloy, composed of 9 parts of palladium and 1 of silver, is used almost exclusively for dental purposes, and is well suited to the manufacture of artificial teeth, as it does not oxidize. An alloy even more frequently used than this consists of platinum 10 parts, palladium 8, and gold 6.

Palladium Bearing Metal.—This alloy is extremely hard, and is used instead of jewel bearings in watches. It is composed of palladium 24 parts, gold 72, silver 44, copper 92.

PLATINUM ALLOYS.

Platinum has usually been alloyed with silver in goldsmith's work, 2 parts silver to 1 of platinum being taken to form the favorite "platinum silver." The object has been to produce an alloy having a white appearance, which can be polished, and at the same time has a low melting point. In addition to this platinum alloy the following are well known:

I.—A mixture of 7 parts platinum with 3 parts iridium. This gives to platinum the hardness of steel, which can be still further increased by taking 4 parts of iridium.

II.—An alloy of 9 parts platinum and 1 part iridium is used by the French in the manufacture of measuring instruments of great resisting power.

Compounds of copper, nickel, cadmium, and tungsten are also used in the construction of parts of watches; the latter acquire considerable hardness without becoming magnetic or rusting like steel.

III.—For this purpose a compound of

62.75 parts platinum, 18 parts copper, 1.25 parts cadmium, and 18 parts nickel is much recommended.

IV.—Very ductile platinum-copper alloys have also been made, e.g., the so-called Cooper gold, consisting of 3 parts platinum and 13 parts copper, which is almost equal to 18-carat gold in regard to color, finish, and ductility. If 4 per cent of platinum is taken, these latter alloys acquire a rose-red color, while a golden-yellow color can be produced by further adding from 1 to 2 per cent (in all 5 to 6 per cent) of platinum. The last-named alloy is extensively used for ornaments, likewise alloy V.

V.—Ten parts platinum, 60 parts nickel, and 220 parts brass, or 2 parts platinum, 1 part nickel and silver respectively, 2 parts brass, and 5 parts copper; this also gives a golden-yellow color.

VI.—For table utensils a favorite alloy is composed of 1 part platinum, 100 parts nickel, and 10 parts tin. Articles made of the latter alloy are impervious to atmospheric action and keep their polish for a long time. Pure white platinum alloys have for some time been used in dental work, and they have also proved serviceable for jewelry.

VII.—A mixture of 30 parts platinum, 10 parts gold, and 3 parts silver, or 7 parts platinum, 2 parts gold, and 3 parts silver.

VIII.—For enameled articles: Platinum, 35 parts; silver, 65 parts. First fuse the silver, then add the platinum in the spongy form. A good solder for this is platinum 80 parts, copper 20 parts.

IX.—For pens: Platinum, 4 parts; silver, 3 parts; copper, 1 part.

Platinum Gold.—Small quantities of platinum change the characteristics of gold in many respects. With a small percentage the color is noticeably lighter than that of pure gold, and the alloys are extremely elastic; alloys containing more than 20 per cent of platinum, however, almost entirely lose their elasticity. The melting point of the platinum-gold alloy is high, and alloys containing 70 per cent of platinum can be fused only in the flame of oxyhydrogen gas, like platinum itself. Alloys with a smaller percentage of platinum can be prepared in furnaces, but require the strongest white heat. In order to avoid the chance of an imperfect alloy from too low a temperature, it is always safer to fuse them with the oxyhydrogen flame. The alloys of platinum and gold have a somewhat limited application. Those which contain from 5 to 10 per cent of platinum are used for sheet and wire in the manufacture of artificial teeth.

Platinum-Gold Alloys for Dental Purposes.—

	I	II	III
Platinum........	6	14	10
Gold............	2	4	6
Silver..........	1	6	..
Palladium.......	..	..	8

Platinum Silver.—An addition of platinum to silver makes it harder, but also more brittle, and changes the white color to gray. An alloy which contains only a very small percentage of platinum is noticeably darker in color than pure silver. Such alloys are prepared under the name of *platine au titre*, containing between 17 and 35 per cent of platinum. They are almost exclusively used for dental purposes.

Imitation Platinum.—I.—Brass, 100 parts; zinc, 65 parts.

II.—Brass, 120 parts; zinc, 75 parts.

III.—Copper, 5 parts; nickel, 4 parts; zinc, 1½ parts; antimony, 1 part; lead, 1 part; iron, 1 part; tin, 1 part.

Cooper's Pen Metal.—This alloy is especially well adapted to the manufacture of pens, on account of its great hardness, elasticity, and power of resistance to atmospheric influences, and would certainly have superseded steel if it were possible to produce it more cheaply than is the case. The compositions most frequently used for pen metal are copper 1 part, platinum 4, and silver 3; or, copper 21, platinum 50, and silver 36.

Pens have been manufactured, consisting of several sections, each of a different alloy, suited to the special purpose of the part. Thus, for instance, the sides of the pen are made of the elastic composition just described; the upper part is of an alloy of silver and platinum; and the point is made either of minute cut rubies or of an extremely hard alloy of osmium and iridium, joined to the body of the pen by melting in the flame of the oxyhydrogen blowpipe. The price of such pens, made of expensive materials and at the cost of great labor, is of course exceedingly high, but their excellent qualities repay the extra expense. They are not in the least affected by any kind of ink, are most durable, and can be used constantly for years without showing any signs of wear.

The great hardness and resistance to the atmosphere of Cooper's alloys make them very suitable for manufacturing

mathematical instruments where great precision is required. It can scarcely be calculated how long a chronometer, for instance, whose wheels are constructed of this alloy, will run before showing any irregularities due to wear. In the construction of such instruments, the price of the material is not to be taken into account, since the cost of the labor in their manufacture so far exceeds this.

PEWTER.

This is an alloy of tin and lead only, or of tin with antimony and copper. The first is properly called pewter. Three varieties are known in trade:

I (Plate Pewter).—From tin, 79 per cent; antimony, 7 per cent; bismuth and copper, of each 2 per cent; fused together. Used to make plates, teapots, etc. Takes a fine polish.

II (Triple Pewter).—From tin, 79 per cent; antimony, 15 per cent; lead, 6 per cent; as the last. Used for minor articles, syringes, toys, etc.

III (Ley Pewter).—From tin, 80 per cent; lead, 20 per cent. Used for measures, inkstands, etc.

According to the report of a French commission, pewter containing more than 18 parts of lead to 82 parts of tin is unsafe for measures for wine and similar liquors, and, indeed, for any other utensils exposed to contact with food or beverages. The legal specific gravity of pewter in France is 7.764; if it be greater, it contains an excess of lead, and is liable to prove poisonous. The proportions of these metals may be approximately determined from the specific gravity; but correctly only by an assay for the purpose.

SILVER ALLOYS:

Aluminum Silver.—Aluminum and silver form beautiful white alloys which are considerably harder than pure aluminum, and take a very high polish. They have the advantage over copper alloys of being unchanged by exposure to the air, and of retaining their white color.

The properties of aluminum and silver alloys vary considerably according to the percentage of aluminum.

I.—An alloy of 100 parts of aluminum and 5 parts of silver is very similar to pure aluminum, but is harder and takes a finer polish.

II.—One hundred and sixty-nine parts of aluminum and 5 of silver make an elastic alloy, recommended for watch springs and dessert knives.

III.—An alloy of equal parts of silver and aluminum is as hard as bronze.

IV.—Five parts of aluminum and 1 part of silver make an alloy that is easily worked.

V.—Also aluminum, 3 parts, and silver, 1 part.

VI. **Tiers-Argent.**—This alloy is prepared chiefly in Paris, and used for the manufacture of various utensils. As indicated by its name (one-third silver), it consists of 33.33 parts of silver and 66.66 parts of aluminum. Its advantages over silver consist in its lower price and greater hardness; it can also be stamped and engraved more easily than the alloys of copper and silver.

VII.—This is a hard alloy which has been found very useful for the operating levers of certain machines, such as the spacing lever of a typewriter. The metal now generally used for this purpose by the various typewriter companies is "aluminum silver," or "silver metal." The proportions are given as follows:

Copper	57.00
Nickel	20.00
Zinc	20.00
Aluminum	3.00

This alloy when used on typewriting machines is nickel-plated for the sake of the first appearance, but so far as corrosion is concerned, nickeling is unnecessary. The alloy is stiff and strong and cannot be bent to any extent without breaking, especially if the percentage of aluminum is increased to 3.5 per cent; it casts free from pinholes and blowholes; the liquid metal completely fills the mold, giving sharp, clean castings, true to pattern; its cost is not greater than brass; its color is silver white, and its hardness makes it susceptible to a high polish.

Arsenic.—Alloys which contain small quantities of arsenic are very ductile, have a beautiful white color, and were formerly used in England in the manufacture of tableware. They are not, however, suitable for this purpose, on account of the poisonous character of the arsenic. They are composed usually of 49 parts of silver, 49 of copper, and 2 of arsenic.

China Silver.—Copper, 65.24 per cent; tin, 19.52 per cent; nickel, 13.00 per cent; silver, 2.05 per cent.

Copper-Silver.—When silver is alloyed with copper only one proportion is known which will give a uniform casting. The proportion is 72 per cent silver to 28 per cent copper. With more silver than 72 per cent the center of a cast bar will be

richer than the outside, which chills first; while with a less percentage than 72 per cent the center of the bar will be poorer and the outside richer than the average. This characteristic of silver-copper alloys is known to metallurgists as "segregation."

When nickel is added to the silver and copper, several good alloys may be formed, as the following French compositions:

	I	II	III
Silver.....	33	40	20
Copper....	37–42	30–40	45–55
Nickel.....	25–30	20–30	25–35

The whitening of alloys of silver and copper is best accomplished by annealing the alloy until it turns black on the surface. Cool in a mixture of 20 parts, by weight, of concentrated sulphuric acid to 1,000 parts of distilled water and leave therein for some time. In place of the sulphuric acid, 40 parts of potassium bisulphate may be used per 1,000 parts of liquid. Repeat the process if necessary.

Copper, Silver, and Cadmium Alloys.—Cadmium added to silver alloys gives great flexibility and ductility, without affecting the white color; these properties are valuable in the manufacture of silver-plated ware and wire. The proportions of the metals vary in these alloys. Some of the most important varieties are given below.

	Silver	Copper	Cadmium
I......	980	15	5
II......	950	15	35
III......	900	18	82
IV......	860	20	180
V......	666	25	309
VI......	667	50	284
VII......	500	50	450

In preparing these alloys, the great volatility of cadmium must be taken into account. It is customary to prepare first the alloy of silver and copper, and add the cadmium, which, as in the case of the alloys of silver and zinc, must be wrapped in paper. After putting it in, the mass is quickly stirred, and the alloy poured immediately into the molds. This is the surest way to prevent the volatilization of the cadmium.

Silver, Copper, Nickel, and Zinc Alloys.—These alloys, from the metals contained in them, may be characterized as argentan or German silver with a certain percentage of silver. They have been used for making small coins, as in the older coins of Switzerland. Being quite hard, they have the advantage of wearing well, but soon lose their beautiful white color and take on a disagreeable shade of yellow, like poor brass. The silver contained in them can be regained only by a laborious process, which is a great drawback to their use in coinage. The composition of the Swiss fractional coins is as follows:

	20 centimes	10 centimes	5 centimes
Silver.........	15	10	5
Copper........	50	55	60
Nickel.........	25	25	25
Zinc...........	10	10	10

Mousset's Alloy.—Copper, 59.06; silver, 27.56; zinc, 9.57; nickel, 3.42. This alloy is yellowish with a reddish tinge, but white on the fractured surface. It ranks next after Argent-Ruolz, which also contains sometimes certain quantities of zinc, and in this case may be classed together with the alloy just described. The following alloys can be rolled into sheet or drawn into wire:

	I	II	III
Silver.......	33.3	34	40.0
Copper......	41.8	42	44.6
Nickel.......	8.6	8	4.6
Zinc.........	16.3	16	10.8

Japanese (Gray) Silver.—An alloy is prepared in Japan which consists of equal parts of copper and silver, and which is given a beautiful gray color by boiling in a solution of alum, to which copper sulphate and verdigris are added. The so-called "mokum," also a Japanese alloy, is prepared by placing thin plates of gold, silver, copper, and the alloy just described over each other and stretching them under the hammer. The cross sections of the thin plates obtained in this way show the colors of the different metals, which give them a peculiar striped appearance. Mokum is principally used for decorations upon gold and silver articles.

Silver-Zinc.—Silver and zinc have great affinity for each other, and alloys of these two metals are therefore easily made. The required quantity of zinc, wrapped in paper, is thrown into the melted and strongly heated silver, the mass is thoroughly stirred with an iron rod, and at once poured out into molds. Alloys of silver and zinc can be obtained which are both ductile and flexible. An alloy consisting of 2 parts of zinc and 1 of silver closely resembles silver in color, and is quite ductile. With a larger proportion of zinc the alloy becomes brittle. In preparing the alloy, a somewhat larger quantity of zinc must be taken than the

finished alloy is intended to contain, as a small amount always volatilizes.

Imitation Silver Alloys.—There are a number of alloys, composed of different metals, which resemble silver, and may be briefly mentioned here.

I.—Warne's metal is composed of tin 10 parts, bismuth 7, and cobalt 3. It is white, fine-grained, but quite difficult to fuse.

II.—Tonca's metal contains copper 5 parts, nickel 4, tin 1, lead 1, iron 1, zinc 1, antimony 1. It is hard, difficult to fuse, not very ductile, and cannot be recommended.

III.—Trabuk metal contains tin 87.5, nickel 5.5, antimony 5, bismuth 5.

IV.—Tourun-Leonard's metal is composed of 500 parts of tin and 64 of bell metal.

V.—Silveroid is an alloy of copper, nickel, tin, zinc, and lead.

VI.—Minargent. Copper, 100 parts; nickel, 70 parts; tungsten, 5 parts; aluminum, 1 part.

VII.—Nickel, 23 parts; aluminum, 5 parts; copper, 5 parts; iron, 65 parts; tungsten, 4 parts.

VIII.—Argasoid. Tin, 4.035; lead, 3.544; copper, 55.780; nickel, 13.406; zinc, 23.198; iron, trace.

SOLDERS:

See Solders.

STEEL ALLOYS:

See also Steel.

For Locomotive Cylinders.—This mixture consists of 20 per cent steel castings, old steel springs, etc.; 20 per cent No. 2 coke iron, and 60 per cent scrap. From this it is stated a good solid metal can be obtained, the castings being free from honeycombing, and finishing better than the ordinary cast-iron mixture, over which it has the advantage of 24 per cent greater strength. Its constituents are: Silicon, 1.51; manganese, 0.33; phosphorus, 0.65; sulphur, 0.068; combined carbon, 0.62; graphite, 2.45.

Nickel steel is composed of nickel 36 per cent, steel 64 per cent.

Tungsten steel is crucible steel with 5 to 12 per cent tungsten.

STEREOTYPE METAL.

Lead	2 parts
Tin	3 parts
Bismuth	5 parts

The melting point of this alloy is 196° F. The alloy is rather costly because of the amount of bismuth which it contains. The following mixtures are cheaper:

	I	II	III	IV
Tin	1	3	1	2
Lead	1	5	1.5	2
Bismuth	2	8	3	5
Antimony	..	..	....	1

TIN ALLOYS:

Alloys for Dentists' Molds and Dies.—I.—Very hard. Tin, 16 parts; antimony, 1 part; zinc, 1 part.

II.—Softer than the former. Tin, 8 parts; zinc, 1 part; antimony, 1 part.

III.—Very hard. Tin, 12 parts; antimony, 2 parts; copper, 1 part.

Cadmium Alloy, about the Hardness of Zinc.—Tin, 10 parts; antimony, 1 part; cadmium, 1 part.

Tin-Lead.—Tin is one of those metals which is not at all susceptible to the action of acids, while lead, on the other hand, is very easily attacked by them. In such alloys, consequently, used for cooking utensils, the amount of lead must be limited, and should properly not exceed 10 or 15 per cent; but cases have been known in which the so-called tin contained a third part, by weight, of lead.

Alloys containing from 10 to 15 per cent of lead have a beautiful white color, are considerably harder than pure tin, and much cheaper. Many alloys of tin and lead are very lustrous, and are used for stage jewelry and mirrors for reflecting the light of lamps, etc. An especially brilliant alloy is called "Fahlun brilliants." It is used for stage jewelry, and consists of 29 parts of tin and 19 of lead. It is poured into molds faceted in the same way as diamonds, and when seen by artificial light, the effect is that of diamonds. Other alloys of tin and lead are employed in the manufacture of toys. These must fill the molds well, and must also be cheap, and therefore as much as 50 per cent of lead is used. Toys can also be made from type metal, which is even cheaper than the alloys of tin and lead, but has the disadvantage of readily breaking if the articles are sharply bent. The alloys of tin and lead give very good castings, if sharp iron or brass molds are used.

Lead	19 parts
Tin	29 parts

This alloy is very bright and possesses a permanent sheen. It is well adapted for the making of artificial gems for stage use. It is customary in carrying out the process to start with two parts of tin and one part of lead. Tin is added until a sample drop which is allowed to fall upon an iron plate forms a mirror. The artificial gems are produced by

dipping into the molten alloy pieces of glass cut to the proper shape. The tin coating of metal which adheres to the glass cools rapidly and adheres tenaciously. Outwardly these artificial gems appear rough and gray, but inwardly they are highly reflective and quite deceptive when seen in artificial light.

If the reflective surfaces be coated with red, blue, or green aniline, various colored effects can be obtained. Instead of fragile glass the gems may be produced by means of well-polished pieces of steel or bronze.

Other Tin-Lead Alloys.— Percentage of lead and specific gravity.

P. C.	S. G.	P. C.	S. G.
0	7.290	28	8.105
1	7.316	29	8.137
2	7.342	30	8.169
3	7.369	31	8.202
4	7.396	32	8.235
5	7.423	33	8.268
6	7.450	34	8.302
7	7.477	35	8.336
8	7.505	36	8.379
9	7.533	37	8.405
10	7.562	38	8.440
11	7.590	39	8.476
12	7.619	40	8.512
13	7.648	41	8.548
14	7.677	42	8.584
15	7.706	43	8.621
16	7.735	44	8.658
17	7.764	45	8.695
18	7.794	46	8.732
19	7.824	47	8.770
20	7.854	48	8.808
21	7.885	49	8.846
22	7.916	50	8.884
23	7.947	60	9.299
24	7.978	70	9.736
25	8.009	80	10.225
26	8.041	90	10.767
27	8.073	100	11.370

Tin Statuettes, Buttons, etc.—

I.—Tin................ 4 parts
Lead................ 3 parts

This is a very soft solder which sharply reproduces all details.

Another easily fusible alloy but somewhat harder, is the following:

II.—Tin................ 8 parts
Lead.............. 6 parts
Antimony......... 0.5 part

Miscellaneous Tin Alloys.—I.—Alger Metal.—Tin, 90 parts; antimony, 10 parts. This alloy is suitable as a protector.

II. Argentine Metal.—Tin, 85.5 per cent; antimony, 14.5 per cent.

III.—Ashberry metal is composed of 78 to 82 parts of tin, 16 to 20 of antimony, 2 to 3 of copper.

IV. Quen's Metal.—Tin, 9 parts; lead, 1 part; antimony, 1 part; bismuth, 1 part.

Type Metal.—An alloy which is to serve for type metal must be readily cast, fill out the molds sharply, and be as hard as possible. It is difficult to satisfy all these requirements, but an alloy of antimony and lead answers the purpose best. At the present day there are a great many formulas for type metal in which other metals besides lead and antimony are used, either to make the alloy more readily fusible, as in the case of additions of bismuth, or to give it greater power of resistance, the latter being of especial importance for types that are subjected to constant use. Copper and iron have been recommended for this purpose, but the fusibility of the alloys is greatly impaired by these, and the manufacture of the types is consequently more difficult than with an alloy of lead and antimony alone. In the following table some alloys suitable for casting type are given:

	Lead	Antimony	Copper	Bismuth	Zinc	Tin	Nickel
I	3	1	..	..	..	..	..
II	5	1	..	..	..	..	..
III	10	1	..	..	..	..	..
IV	10	2	..	1	..	..	..
V	70	18	2	..	..	10	..
VI	60	20	..	..	..	20	..
VII	55	25	..	..	..	20	..
VIII	55	30	..	..	..	15	..
IX	100	30	8	2	..	20	8
X	6	..	4	..	90	..	..

The French and English types contain a certain amount of tin, as shown by the following analyses:

	English Types I	English Types II	English Types III	French Types
Lead	69.2	61.3	55.0	55
Antimony	19.5	18.8	22.7	30
Tin	9.1	20.2	22.1	15
Copper	1.7	....	....	..

Ledebur gives the composition of type metal as follows:

	I	II	III	IV
Lead	75	60	80	82
Antimony	23	25	20	14.8
Tin	22	15	..	3.2

WATCHMAKERS' ALLOYS:

See Watchmakers' Formulas.

WHITE METALS.

The so-called white metals are employed almost exclusively for bearings. (See Anti-friction Metals under Alloys.) In the technology of mechanics an accurate distinction is made between the different kinds of metals for bearings; and they may be classed in two groups, red brass and white metal. The red-

brass bearings are characterized by great hardness and power of resistance, and are principally used for bearings of heavily loaded and rapidly revolving axles. For the axles of large and heavy fly-wheels, revolving at great speed, bearings of red brass are preferable to white metal, though more expensive.

In recent years many machinists have found it advantageous to substitute for the soft alloys generally in use for bearings a metal almost as hard as the axle itself. Phosphor bronze (q. v.) is frequently employed for this purpose, as it can easily be made as hard as wrought or cast steel. In this case the metal is used in a thin layer, and serves only, as it were, to fill out the small interstices caused by wear on the axle and bearing, the latter being usually made of some rather easily fusible alloy of lead and tin. Such bearings are very durable, but expensive, and can only be used for large machines. For small machines, running gently and uniformly, white-metal bearings are preferred, and do excellent work, if the axle is not too heavily loaded. For axles which have a high rate of revolution, bearings made of quite hard metals are chosen, and with proper care —which, indeed, must be given to bearings of any material—they will last for a long time without needing repair.

White Metal for Bearing.

		Tin	Antimony	Zinc	Iron	Lead	Copper
I	German, light loads.....	85.00	10.00	......	......	......	5.00
II	German, light loads.....	82.00	11.00	......	......	......	7.00
III	German, light loads.....	80.00	12.00	......	......	......	8.00
IV	German, light loads.....	76.00	17.00	......	......	......	7.00
V	German, light loads.....	3.00	1.00	5.00	......	3.00	1.00
VI	German, heavy loads...	90.00	8.00	......	......	......	2.00
VII	German, heavy loads...	86.81	7.62	......	......	......	5.57
VIII	English, heavy loads....	17.47	......	76.14	......	......	5.62
IX	English, medium loads..	76.70	15.50	......	......	......	7.80
X	English, medium loads..	72.00	26.00	......	......	......	2.00
XI	For mills..............	15.00	......	40.00	......	42.00	3.00
XII	For mills	......	1.00	5.00	......	5.00	....
XIII	For mills..............	......	1.00	10.00	......	2.00	....
XIV	Heavy axles...........	72.70	18.20	......	......	......	9.10
XV	Heavy axles	38.00	6.00	47.00	......	4.00	1.00
XVI	Rapidly revolving axles.	17.00	77.00	......	......	......	6.00
XVII	Very hard metal.......	55.00	......	......	70.00	......	2.50
XVIII	Very hard metal.......	12.00	82.00	2.00	......	......	4.00
XIX	Cheap metal...........	2.00	2.00	88.00	......	......	8.00
XX	Cheap metal...........	1.50	1.50	90.00	......	......	7.00

Other white bearing metals are:

XXI.—Tin, 8.5; antimony, 10; copper, 5 parts.

XXII.—Tin, 42; antimony, 16; lead, 42 parts.

XXIII.—Tin, 72; antimony, 26; copper, 2 parts.

XXIV.—Tin, 81; antimony, 12.5; copper, 6.5 parts.

White Metals Based on Copper.—

I.—Copper, 65 parts; arsenic, 55 parts.

II.—Copper, 64 parts; arsenic, 50 parts.

III.—Copper, 10 parts; zinc, 20 parts; nickel, 30 parts.

IV.—Nickel, 70 parts; copper, 30 parts; zinc, 20 parts.

V.—Nickel, 60 parts; copper, 30 parts; zinc, 30 parts.

VI.—Copper, 8 parts; nickel, 4 parts; zinc, 4 parts.

VII.—Copper, 10 parts; nickel, 5 parts; zinc, 5 parts.

VIII.—Copper, 8 parts; nickel, 3 parts; zinc, 4 parts.

IX.—Copper, 50 parts; nickel, 25 parts; zinc, 25 parts.

X.—Copper, 55 parts; nickel, 24 parts; zinc, 21 parts.

XI.—Copper, 55 parts; nickel, 24 parts; zinc, 16 parts; iron, 2 parts; tin, 3 parts.

IX, X, and XI are suitable for tableware.

XII.—Copper, 67 parts, and arsenic, 53 parts.

XIII.—Copper, 63 parts, and arsenic, 57 parts.

XII and XIII are bright gray, unaffected by the temperature of boiling water; they are fusible at red heat.

White Metals Based on Platinum.—

I.—Platinum, 1 part; copper, 4 parts; or platinum, 1½ parts; copper, 3½ parts.

II.—Platinum, 10 parts; tin, 90 parts; or platinum, 8 parts; tin, 92 parts.

III.—Platinum, 7 parts; copper, 13 parts; tin, 80 parts.

IV.—Platinum, 2 parts; steel, 98 parts.

V.—Platinum, 2.5 parts; steel, 97.5 parts.

IV and V are for gun metal.

Miscellaneous White-Metal Alloys.—

I.—For lining cross-head slides: Lead, 65 parts; antimony, 25 parts; copper, 10 parts. Some object to white metal containing lead or zinc. It has been found, however, that lead and zinc have properties of great use in these alloys.

II.—Tin, 85 parts; antimony, 7½ parts; copper, 7½ parts.

III.—Tin, 90 parts; copper, 3 parts; antimony, 7 parts.

ZINC ALLOYS:

Bidery Metal.—This is sometimes composed of 31 parts of zinc, 2 parts of copper, and 2 parts of lead; the whole is melted on a layer of rosin or wax to avoid oxidation. This metal is very resistive; it does not oxidize in air or moisture. It takes its name from the town of Bider, near Hyderabad (India), where it was prepared for the first time industrially for the manufacture of different utensils.

Other compositions of Indian Bidery metal (frequently imitated in England) are about as follows:

	P.C.	P.C.	P.C.
Copper...	3.5	11.4	16
Zinc......	93.4	84.3	112
Tin......	....	1.4	2
Lead.....	3.1	2.9	4

Erhardt recommends the following as being both ductile and hard:

Zinc...............	89 to 93
Tin...............	9 to 6
Lead...............	2 to 4
Copper.............	2 to 4

The tin is first melted, and the lead, zinc, and copper added successively.

Zinc-Nickel.—Zinc, 90 parts; nickel, 10 parts. Used in powder form for painting and cloth printing purposes.

Platine for Dress Buttons.—Copper, 43 parts; zinc, 57 parts.

UNCLASSIFIED ALLOYS:

Alloys for Drawing Colors on Steel.—Alloys of various composition are successfully used for drawing colors on steel. To draw to a straw color use 2 parts of lead and 1 part of tin, and melt in an iron ladle. Hold the steel piece to be drawn in the alloy as it melts and it will turn to straw color. This mixture melts at a temperature of about 437° F. For darker yellow use 9 parts of lead to 4 parts of tin, which melts at 458° F. For purple, use 3 parts of lead to 1 part of tin, the melting temperature being 482° F. For violet, use 9 parts of lead to 2 parts of tin, which melts at 494° F. Lead without any alloy will draw steel to a dark blue. The above apply to steel only since iron requires a somewhat greater heat and is more or less uncertain in handling.

Alloy for Pattern Letters and Figures.—A good alloy for casting pattern letters and figures and similar small parts of brass, iron, or plaster molds, is made of lead 80 parts, and antimony 20 parts. A better alloy will be lead 70 parts, antimony and bismuth each 15 parts. To insure perfect work the molds should be quite hot by placing them over a Bunsen burner.

Alloy for Caliper and Gage-Rod Castings.—A mixture of 30 parts zinc to 70 parts aluminum gives a light and durable alloy for gage rods and caliper legs; the gage rods must be steel tipped, for the alloy is soft and wears away too rapidly for gage points.

Alloys for Small Casting Molds.—Tin, 75 parts, and lead, 22 parts; or 75 parts of zinc and 25 parts of tin; or 30 parts of tin and 70 parts of lead; or 60 parts of lead and 40 parts of bismuth.

ALLOYS FOR METAL FOIL:
See Metal Foil.

ALMOND COLD CREAM:
See Cosmetics.

ALMOND LIQUEURS:
See Wines and Liquors.

ALTARS, TO CLEAN:
See Cleaning Preparations and Methods.

ALUM:

Burnt Alum.—I.—Heat the alum in a porcelain dish or other suitable vessel till it liquefies, then raise and continue the heat, not allowing it to exceed 400°, till aqueous vapor ceases to be disengaged, and the salt has lost 47 per cent of its weight. Reduce the residue to powder, and preserve it in a well-stoppered bottle.—*Cooley.*

II.—Heat ordinary alum (alumina alum) with constant stirring in an iron pan in which it will first melt quietly, and then commence to form blisters. Continue heating until a dry white mass of a loose character remains, which is powdered and kept in well-closed glasses.

ALUM BATH:
See Photography.

Aluminum and its Treatment

HOW TO COLOR ALUMINUM:

Blanching of Aluminum.—Aluminum is one of the metals most inalterable by air; nevertheless, the objects of aluminum tarnish quickly enough without being

altered. They may be restored to their mat whiteness in the following manner: Immerse the aluminum articles in a boiling bath of caustic potash; next plunge them quickly into nitric acid, rinse and let dry. It must be understood that this method is applicable only to pieces entirely of aluminum.

Decolorized Aluminum.—Gray or unsightly aluminum may be restored to its white color by washing with a mixture of 30 parts of borax dissolved in 1,000 parts of water, with a few drops of ammonia added.

Mat Aluminum.—In order to impart to aluminum the appearance of mat silver, plunge the article into a hot bath composed of a 10-per-cent solution of caustic soda saturated with kitchen salt. Leave it in the bath for 15 to 20 seconds, then wash and brush; put back into the bath for half a minute, wash anew and dry in sawdust.

To Blacken Aluminum.—I.—The surface of the sheet to be colored is polished with very fine emery powder or finest emery cloth. After polishing pour a thin layer of olive oil over the surface and heat slowly over an alcohol flame. Large sheets must, of course, be heated in the drying oven. After a short while pour on oil again, in order to obtain absolute uniformity of the coating, and heat the plate once more. Under the action of the heat the plate turns first brown, then black, according to the degrees of heat. When the desired coloration has been attained, the plate is polished over again, after cooling, with a woolen rag or soft leather.

II.—White arsenic	1 ounce
Sulphate of iron	1 ounce
Hydrochloric acid ..	12 ounces
Water	12 ounces

When the arsenic and iron are dissolved by the acid add the water. The aluminum to be blackened should be well cleaned with fine emery powder and washed before immersing in the blackening solution. When the deposit of black is deep enough dry off with fine sawdust and lacquer.

Decorating Aluminum.—A process for decorating aluminum, patented in Germany, prescribes that the objects be first corroded, which is usually done with caustic soda lye, or, better still, by a new method which consists in heating 3 parts of sulphuric acid with 1 part of water to 140° to 158° F., in an enameled vessel. Into this liquid dip the aluminum articles, rinsing them off clean and then drying them well. The corroded articles are now placed in a bath consisting of 1,000 parts of alcohol (90 per cent), 1.50 parts of antimony, 250 parts of chemically pure hydrochloric acid, 100 parts of manganous nitrate, and 20 parts of purified and finally elutriated graphite. In this bath, which is heated to 86°–95° F., the objects are left until fumes develop around them, which takes place in a few seconds. Now they are put over a coal fire or similar arrangement until the alcohol is burned up and there is no more smoke. After they are somewhat cooled off, they are laid into cold water and worked with a brush, then rinsed with water and well dried. The pieces are now provided with a gray metallic coating, consisting mainly of antimony, manganese, and graphite. This metallic layer renders them capable of receiving a lacquer which is best prepared from 1,000 parts of alcohol (90 per cent), 50 parts of sandarac, 100 parts of shellac, and 100 parts of nigrosine (black aniline color). Then the articles are quickly but thoroughly rinsed off, dried in warmed air for a few minutes, and baked in ovens or over a moderate coal fire until they do not smoke any more and no more gloss can be seen. Finally they are rubbed with a cotton rag saturated with thin linseed-oil varnish, and the objects thus treated now appear dull black, like velvet. The covering withstands all action of the weather, so that cooking vessels coated with this varnish on the outside can be placed on the fire without injury to the coating. If the articles are engraved, the aluminum appears almost glossy white under the black layer at the engraved places. When the pieces have been provided with the gray metallic coating, colored lacquer may also be applied with the brush. In this manner paintings, etc., may be done on aluminum, while not possible on unprepared aluminum surfaces, which will not retain them.

Making Castings in Aluminum.—The method adopted in preparing molds and cores for aluminum work is necessarily somewhat the same as for brass, but there are particular points which need attention to insure successful work. Both in the sand and the making of the molds there are some small differences which make considerable variation in the results, and the temperature at which the metal is poured is a consideration of some importance.

In selecting the sand, which should

not have been previously used, that of a fine grain should be chosen, but it should not have any excess of aluminous matter, or it will not permit of the free escape of gases and air, this being an important matter. Besides this, the sand must be used as dry as possible consistent with its holding against the flow of the metal, and having only moderate compression in ramming.

In making the molds it is necessary to remember that aluminum has a large contraction in cooling, and also that at certain temperatures it is very weak and tears readily, while all metals shrink away from the mold when this is wholly outside the casting, but they shrink on to cores or portions of the mold partly inclosed by metal. Thus, if casting a plate or bar of metal, it will shrink away from the mold in all directions; but if casting a square frame, it shrinks away from the outside only, while it shrinks on to the central part or core. With brass, or iron, or such metals, this is not of much importance, but with some others, including aluminum, it is of great importance, because if the core or inclosed sand will not give somewhat with the contraction of the metal, torn or fractured castings will be the result. Both for outside and inside molds, and with cores used with aluminum, the sand should be compressed as little as possible, and hard ramming must in every case be avoided, particularly where the metal surrounds the sand. The molds must be very freely vented, and not only at the joint of the mold, but by using the vent wire freely through the body of the mold itself; in fact, for brass the venting would be considered excessive. With aluminum it is, however, necessary to get the air off as rapidly as possible, because the metal soon gets sluggish in the mold, and unless it runs up quickly it runs faint at the edges. The ingates should be wide and of fair area, but need careful making to prevent their drawing where they enter the casting, the method of doing this being known to most molders.

If it is considered desirable to use a specially made-up facing sand for the molds where the metal is of some thickness, the use of a little pea or bean meal will be all that is necessary. To use this, first dry as much sand as may be required and pass through a 20-mesh sieve, and to each bushel of the fine sand rub in about 4 quarts of meal, afterwards again passing through the sieve to insure regular mixing. This sand should then be damped as required, being careful that all parts are equally moist, rubbing on a board being a good way to get it tough, and in good condition, with the minimum of moisture.

The molds should not be slecked with tools, but they may be dusted over with plumbago or steatite, smoothing with a camel's-hair brush, in cases in which a very smooth face is required on the castings. Preferably, however, the use of the brush even should be avoided. Patterns for aluminum should be kept smooth and well varnished.

In melting the metal it is necessary to use a plumbago crucible which is clean and which has not been used for other metals. Clay or silica crucibles are not good for this metal, especially silica, on account of the metal absorbing silicon and becoming hard under some conditions of melting. A steady fire is necessary, and the fuel should reach only about halfway up the crucible, as it is not desirable to overheat the crucible or metal. The metal absorbs heat for some time and then fuses with some rapidity, hence the desirability of a steady heat; and as the metal should be poured when of a claret color under the film of oxide which forms on the surface, too rapid a heating is not advisable. The molding should always be well in advance of the pouring, because the metal should be used as soon as it is ready; for not only is waste caused, but the metal loses condition if kept in a molten state for long periods. The metal should be poured rapidly, but steadily, and when cast up there should not be a large head of metal left on top of the runner. In fact, it is rather a disadvantage to leave a large head, as this tends to draw rather than to feed the casting.

With properly prepared molds, and careful melting, fluxes are not required, but ground cryolite—a fluoride of sodium and aluminum—is sometimes used to increase the fluidity of the metal. In using this, a few ounces according to the bulk of metal to be treated is put into the molten metal before it is taken from the furnace, and well stirred in, and as soon as the reaction apparently ceases the pot is lifted and the metal at once skimmed and poured. The use of sodium in any form with aluminum is very undesirable, however, and should be avoided, and the same remark applies to tin, but there is no objection to alloying with zinc, when the metal thus produced is sold as an alloy.

Aluminum also casts very well in molds of plaster of Paris and crushed bath brick when such molds are perfectly dry